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LapseAnalyzer: A Web-based Visual Analytics Tool for Aiding Smoking Cessation

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1. INTRODUCTION

Smoking is one of the most challenging behavioral health problems with a single digit cessation success rate [1, 2]. Recently there has been growing interest in designing smoking cessation systems utilizing objective data collected from wearable sensors [4]. Many of these systems are designed as mobile applications, offering visualization to support cessation effort. While portability of mobile devices makes these applications accessible anywhere, they limit the types of visualization that can be offered and restrict the types of activities that can be performed.

In our research, we developed a web-based visual analytics tool, LapseAnalyzer, to support complex analysis of smoking datasets. To create the visualizations, we analyzed physiological data collected via wearable devices as part of a four-day pre-quit post-quit study (N=55). LapseAnalyzer has two main objectives. First, it helps individuals gain a better understanding of the smoking history, lapse pattern and risk factors. Second, it assists health researchers with identifying trends and discovering factors that contribute to lapse.

We believe LapseAnalyzer will advance understanding of the complexities surrounding design of intelligent predictive models to aid smoking cessation. While we focus on smoking here, our approach could be generalized to address other behavioral health problems such as depression, drug and alcohol addiction, and eating disorders.

2. SYSTEM DESIGN

LapseAnalyzer offers two categories of interactive visualizations: 1) participant-centric visualizations enabling exploration, pattern finding, and reflection, and 2) expert-centric visualizations supporting trend finding, comparison, and event-of-interest detection. The main interface of LapseAnalyzer is divided into two panels – the left facilitates selection of visualization parameters and data sets, while the right panel displays the visualizations for analysis. All visualizations created by selecting appropriate parameters can also be saved for later analysis or shared with others (e.g., doctors, family or friends) without needing to re-enter the visualization parameters. We developed our system using Bootstrap and D3.js. As such, LapseAnalyzer can run on any modern web browser. Currently, LapseAnalyzer offers six unique visualizations targeted to support different types of analysis on the smoking dataset. In this section, we briefly introduce each of the visualizations and discuss rational for creating them.

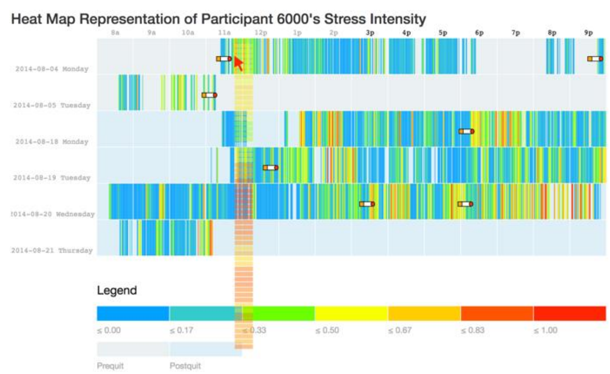

Figure 1: Heat Map Visualization showing stress and smoking history. Here, X-axis indicates time-of-day, Y-axis indicates different days-of-the-week, and color indicates stress intensity.

2.1 Heat Map Visualization

We created heat map visualization (see Fig. 1) to provide an overview of an individual's smoking and stress data. Heat map is ideal for representing such large data succinctly, as each small vertical slice can represent a minute or even hour worth of data, and helps to identify temporal patterns easily. For example, Fig. 1 shows that participant 6000 experienced a spike in stress intensity at 11:30am on the first day of the study, around 30 minutes after experiencing a lapse. Fig. 1 also show that while all smoking events were not preceded by high stress periods, all of these lapses resulted in high-stress periods in close temporal proximity.

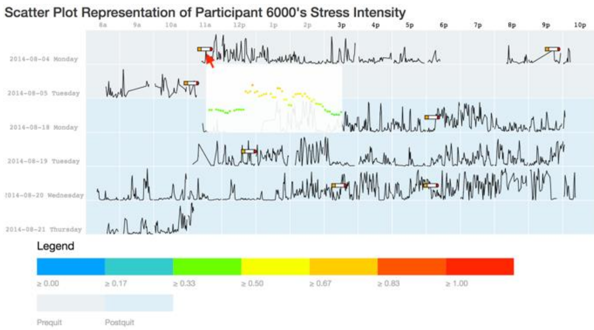

Figure 2: Scatter plot visualization with each row showing data from a day and X-axis showing time.

2.2 Scatter Plot Visualization

We created scatter plot visualization (Fig. 2) to highlight momentary change in stress data and its relationship with smoking. While heat maps are ideal to offer summary/overview of data collected from a designated period, scatter plots highlight every detail included in the dataset. For example, summarizing stress data over any period of time (e.g., 10 minutes) may lose information about a sudden spike of stress resulting from a sudden hard break while driving or a negative interaction with a friend or colleague. However, scatter plots will capture all such events and show how these events influenced subsequent stress and smoking behavior. For example, Fig. 1 and 2 show the same lapse event, however, Fig. 2 offers details about how stress intensity changed from low to high leading to lapse.

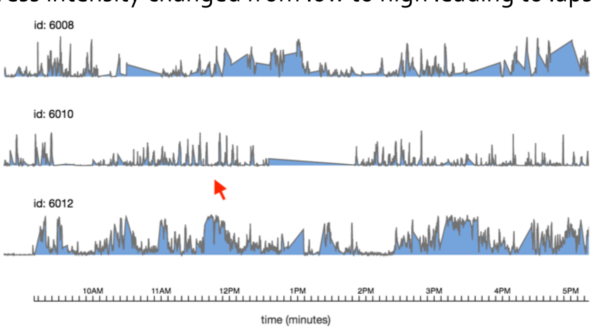

Figure 3: Small multiples visualization highlighting three participants pre-quit data.

2.3 Small Multiples Visualization

Small multiples visualization (Fig. 3) enables comparison of smoking data from different participants. Several graphs are plotted using the same timescale to identify patterns in temporal behavior of the participants. This visualization is especially effective to identify similarities and differences in different cohorts of users by plotting their graphs together. Fig. 3, for example, shows pre-quit data from three participants. Examination of the visualization shows that each of the participants experienced spikes in their stress intensities just before 12pm on a pre-quit day of the study.

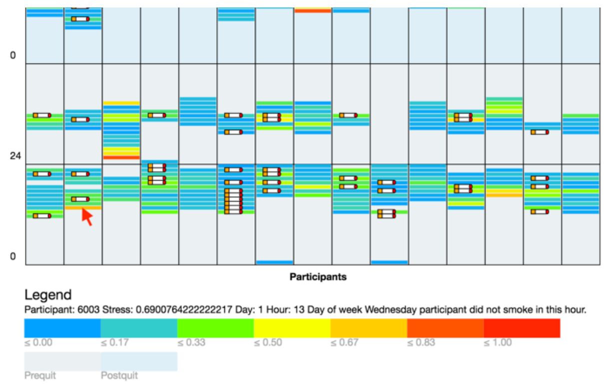

Figure 4: Stacked bar chart enabling comparison between different days for the same participant and similar days from many participants. Each row represents a day and each column represents a participant.

2.4 Stacked Bar Chart Visualization

Stacked bar visualization (Fig. 4) is an expert-centric visualization enabling comparison among different days' data from the same participant and similar days' data from many participants succinctly. Each column in Fig. 4 represents data from one participant and the three rows represent three different post-quit days for all participants, supporting simultaneous comparison in multiple dimensions. For example, Fig. 4 shows all participants stress levels in all the post-quit days along with how a single user's smoking behavior changed during these three days.

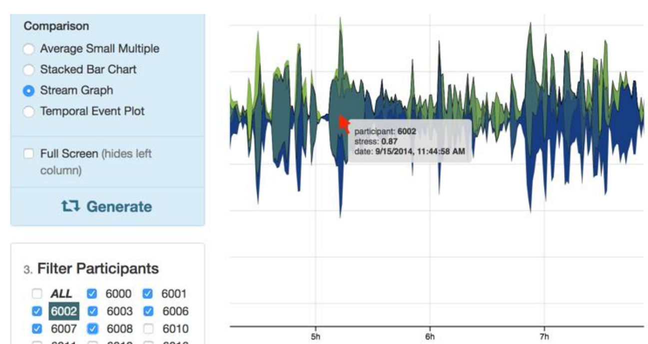

Figure 5: Stream graph highlighting influence of interval on smoking behavior.

2.5 Stream Graph Visualization

Stream graph representation (Fig. 5) uses event alignment to highlight trends and patterns pertaining to time intervals. The aim of this graph is to understand if passing time after the quit event has any influence on stress level. As such, this visualization focuses on the first three post-quit days of each participant's data, and "expands" from the center of the Y-axis as more participants experience higher stress intensities at a given time. Unlike other visualizations, participant's stress levels at a given moment are represented by the "area" allotted to that color in the graph, more specifically the area between the starting and ending points of that color when looking at a small vertical slice of the graph.

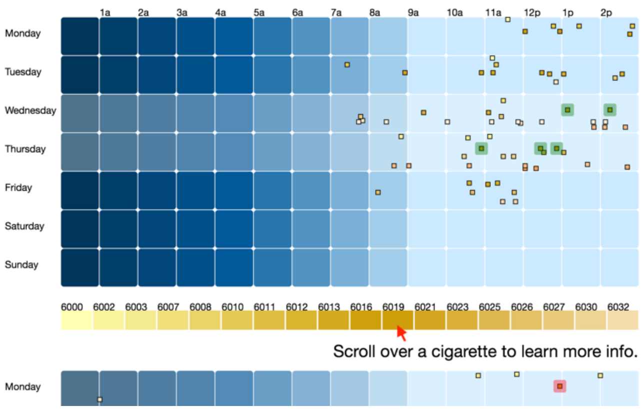

Figure 6: Temporal event visualization highlighting influence of time on smoking. Each row represents a day-of-week and each column represents an hour in a day.

2.6 Temporal Event Visualization

We created temporal event visualization (Fig. 6) which focuses on lapse events rather than stress intensity, and aims to indicate if there are particular times of day where everyone is susceptible to lapse. Events are marked on the graph as small squares, and their colors correspond to the legend and participant IDs listed in the middle. For example, Fig. 6 shows that participant 6019 experienced five pre-quit-date lapses that all fell on Wednesdays and Thursdays between the hours of 10am and 2pm, an area where many other participants' lapse events also occurred.

3. LESSONS LEARNED AND FUTURE WORK

- Participant-centric and expert-centric visualizations can be enriched by adding cohort data. To support long-term behavior change of individuals, it is imperative to support relatedness [3], a concept that highlights how someone is doing with respect to his/her peers. Additionally, to identify temporal and interval influence on smoking and to identify patterns and trends, it is essential to have access to population-scale data. While useful, incorporation of data from many users increase privacy risks and designers have to critically think about how to create visualizations mitigating such risks.
- We created six different types of visualizations focusing on parameters such as time-of-day, day-of-week, interval from an event of interest, etc. Each of these visualizations offer different insights related to how, when and why people lapse. As lapse is complex and often personal, supporting many different visualizations is key to offer deep understanding about factors influencing lapse.
- Wearable technology provides access to vast amounts of physiological and contextual data, however, we still experience difficulty in capturing some types of data continuously. For example, due to privacy concerns, we can't collect information about social situation, audio or video, which could enrich the quality of these visualizations. To overcome these challenges, one of our future goals is to investigate visualization techniques that enable seamless incorporation of continuous time-series data (stress, activity intensity) and discrete categorical data (social situation, geographic location).

4. CONCLUSION

We presented the design of LapseAnalyzer, a web based visual analytics tool for analyzing smoking behavior. We strongly believe that our proposed visualizations will support understanding the complexities surrounding smoking cessation and open up numerous opportunities for researchers and designers of affective technology.

5. REFERENCES

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APPENDIX

Video demonstration of the prototype can be found at: https://www.youtube.com/playlist?list=PL_oWF9Hkq1SIsQsovaWQIJzIJSJ33btKl